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MATHEMATICAL MODEL FOR POST AERATION

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MATHEMATICAL MODEL FOR POST AERATION

By

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This report presents design and cost estimating relationships for post aeration after the activated sludge process. Three specific types of post aeration processes are considered: first, mechanical aerators in completely mixed rectangular basins; second, air diffusers mounted in the outlet channel for the plant; and third, air diffusers mounted in rectangular completely mixed concrete basins. The cost of all three types of post aeration is given for 1-, 3-, 10-, 30-, and 100-mgd plants. The cost of the complete plant is given for comparison with the cost of post aeration.

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent comtamination and to recycle valuable resources.

As part of these activities, the study described here presents the design and cost estimating relationships for post aeration after the activated sludge process.

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Director
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Research Center, Cincinnati

ABSTRACT

This report presents design and cost estimating relationships for post aeration after the activated sludge process. Three specific types of post aeration processes are considered. First, mechanical aerators in completely mixed rectangular basins, second, air diffusers mounted in the outlet channel for the plant, and third, air diffusers mounted in rectangular completely mixed concrete basins. The cost of all three types of post aeration is given for 1, 3, 10, 30, and 100 mgd plants. The cost of the complete plant is given for comparison with the cost of post aeration.

MATHEMATICAL MODEL FOP POST AERATION

This report describes the rationale used and the assumptions made in developing a digital computer program for designing and estimating the cost of post aeration facilities for use downstream of municipal wastewater treatment plants. Three specific types of processes are considered. First, mechanical aerators in completely mixed rectangular basins, second, air diffusers mounted in the outlet channel for the plant (plug flow is assumed) and third, air diffusers mounted in rectangular completely mixed concrete basins.

The FORTRAN method of writing mathematical equations will be used in this report. For an explanation of the FORTRAN method see the Appendix.

The rate at which oxygen can be dissolved in water by means of mechanical aerators or diffused air equipment can be expressed in terms of milligrams per liter of oxygen per day as follows:

$$(mg/l)/day = HP*HPHRO*24/8.33/VMG \quad \text{(mechanical aeration)} \tag{1}$$

$$(mg/l)/day = CFM*AERFF*24*60*.075*.232/8.33/VMG \quad \text{(diffused air)} \tag{2}$$

In equation (1) the term HP is the installed brake horsepower of the aerator, HPHRO is the oxygen transfer rate in pounds of oxygen dissolved per brake horsepower-hour. The term VMG is the volume of the aeration basin in millions of gallons. Aeration efficiency (AERFF) is defined as the fraction of the air delivered to the water which is dissolved in the water. The number (.075) is the density of air at standard conditions, the number (.232) is the fraction of atmospheric air which is oxygen. The term CFM is the standard cubic feet of air per minute delivered to the aeration basin.

When secondary effluent from the activated sludge process is being aerated, some of the oxygen can be used by the active solids and the substrate (BOD) which escape over the weirs of the final settler. The oxygen uptake rate can be simply represented as follows:

$$O_2 \text{ uptake, (mg/l)/day} = .58*CAER*XA*S/CY + 1.16*CE*XA = AERK2 \qquad (3)$$

The first term represents the oxygen used for synthesis and the second term represents the oxygen used for endogenous respiration. The term CAER is the rate constant for synthesis and has a value of 0.03 at 20°C. The term XA is the concentration of active solids (mg/l) which escape over the weirs. The term S represents the BOD concentration (mg/l) in the secondary effluent. The term CY is the yield coefficient and has a value of 0.65. The rate constant for endogenous respiration is CE and the value is 0.125 at 20°C. When the EXECUTIVE PROGRAM[1] is used the values for S and XA can be picked up from the subroutine for activated sludge. A nominal value for XA might be about 8 mg/l. The value for S might be 15-20 mg/l BOD. Biological oxygen uptake will be small in most designs for post aeration.

Another term which must be considered is the flux of oxygen carried into and out of the post aeration basin with the main stream. This can be expressed as follows:

$$\text{(mg/l)/day} = Q*(DOUT-DOIN)/VMG \qquad (4)$$

In this equation the average flow through the aeration basin is Q million gallons per day. The concentration of dissolved oxygen (mg/l) into the basin is DOIN and the concentration of dissolved oxygen out of the basin is DOUT.

If we wish to solve for the horsepower of the mechanical aerator, we can take the expression on the right side of equation (1) and

subtract the right sides of equations (3) and (4). This expression must then be equal to zero for the steady state case since the rate of change of dissolved oxygen in the basin must be zero. The following relationship results:

$$HP = (Q*(DOUT-DOIN) + AERK2*VMG)*8.33/HPHRO/24. \quad (5)$$

To solve equation (5) for the horsepower of the mechanical aerator, we must have the volume of the aeration basin (VMG). Actually, the size of the aeration basin required is a function of the mechanical aerator horsepower. The width and depth of the basin as a function of the aerator horsepower is expressed by the following equations:

$$\text{Basin Width, ft.} = 17 + 0.53*HP \quad \text{(low speed)} \quad (6)$$

$$\text{Basin Width, ft.} = 16 + 0.38*HP \quad \text{(high speed)} \quad (7)$$

$$\text{Basin Depth, ft.} = 5 + 0.07*HP \quad (8)$$

To solve for aerator horsepower, using equation (5), it is only necessary to set VMG equal to zero for the first calculation. Using the computed value for horsepower (HP), the volume of the basin is then found from equations (6), (7), and (8). This new value for VMG is then used to recompute HP from equation (5). This iteration is continued until HP or VMG ceases to vary more than a specified amount. The tolerance on VMG used in the computer program was 0.0001 mg.

The approach used to solve the diffused air case is first to specify the scfm per diffuser (CFMDF) and the number of diffusers per foot of tank or channel length (DIFFT). If we let TD equal the tank or channel depth in feet and TW equal the tank or channel width in feet, the scfm per million gallons (CFMMG) is computed as follows:

$$CFMMG = CFMDF*DIFFT*1000000./TD/TW/7.48 \quad (9)$$

To solve for the case of completely mixed diffused air, the procedure given for mechanical air can be used. From the right side of equation (2) subtract the right sides of equations (3) and (4). This expression must now be zero for the steady state case. The following relationship results:

VMG = Q*(DOUT-DOIN)/(CFMMG*AERFF*24.*60.*.075*.232/8.33 - AERK2) (10)

The detention time for the completely mixed diffused air case can now be readily computed as VMG/Q and the length of the basin in feet is given by the following equation:

TLEN = VMG*1000000./TD/TW/7.48 (11)

So far we have assumed that the values for AERFF and HPHRO are known. Actually, the values for these efficiency measures are quoted only at standard conditions. Standard conditions are zero dissolved oxygen concentration in the water, a water temperature of 20°C, clean tap water, a specific value for depth of the diffuser, the scfm per diffuser, and a given diffuser spacing. The efficiency measure for mechanical aerators (HPHRO) also depends on factors such as speed of rotation, aerator size, depth of submergence, etc.

To correct the efficiency measures AERFF and HPHRO from standard conditions to field conditions, we must first compute the saturation value for dissolved oxygen at the temperature of the water in the aerator. The following relationship[1] can be used for clean tap water at sea level:

CSS, mg/l = 14.652-.41022*TL + .0079910*TL**2.-.000077774*TL**3. (12)

To convert this saturation value to field conditions, the following relationship is used:

CSW, mg/l = CSS*RP*BETA (13)

In equation (13) BETA is a correction factor to take account of the effect of the pollutants in the water. The value of BETA for secondary effluent is about 0.95. The term RP is the ratio of atmospheric pressure at the plant site divided by atmospheric pressure at sea level. The aeration efficiency can now be converted from standard conditions to site conditions by the following relationship given by Kormanik[2]:

```
AERFF = AERFO*(DD/13)**.666*(8/CFMDF)**.2*(CSW-DOUT)/(9.02-0)*
        ALPHA*1.025**(TL-20.)                                    (14)
```

The aeration efficiency at standard conditions was measured at a water depth of 13 ft. and with the scfm per diffuser set at 8 scfm. The factor ALPHA is a correction on aeration efficiency to take account of the pollutants present in the wastewater. The saturation value for pure water (20°C) at sea level is 9.02 mg/l. The aeration efficiency is also corrected for water temperature in the above relationship.

Alternatively, if the performance characteristics of the air diffusers to be used are known, the standard aeration efficiency can be read at the design depth of submergence and air flow rate per diffuser. Performance characteristics for two kinds of diffusers manufactured by Pacific Flush Tank Division of Rex Chainbelt Inc. are shown in Figures 1 and 2. The recommended maximum air flow per diffuser is usually given as 15 scfm per diffuser. The diffusers are positioned one or two feet from the tank bottom. When performance characteristics are available AERFO is converted to field conditions by the following relationship:

```
AERFF = AERFO*(CSW-DOUT)/9.02*ALPHA*1.025**(TL-20)
```

The closest recommended spacing for diffusers is about one diffuser per foot of tank length. It is possible to place diffusers on both sides of the tank and then the value for DIFFT would be 2.

In the sample calculations given in this report, a spacing of one diffuser per foot of tank length has been used, and the relationship

REX CHAINBELT INC.

PACIFIC FLUSH TANK DIVISION
4241 Ravenswood Avenue
Chicago, Illinois 60613
(312) 935-3141

AIR LOCK CROWN DIFFUSER

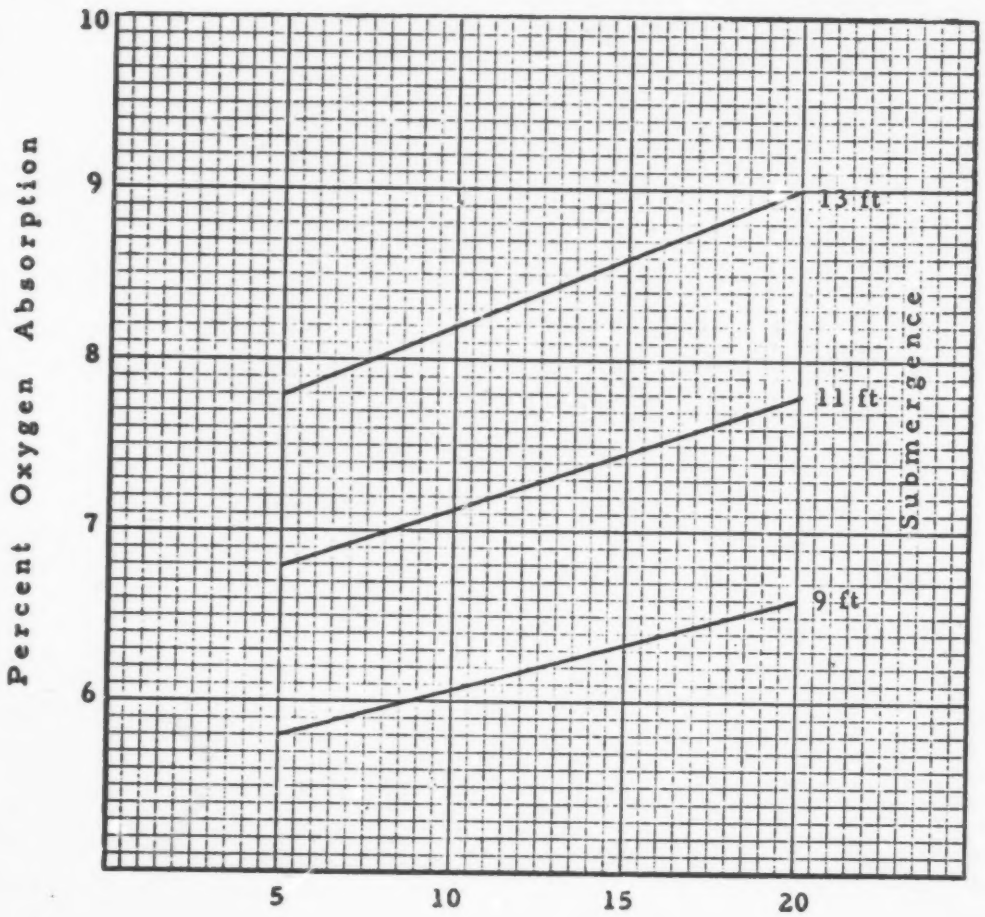


Figure 1

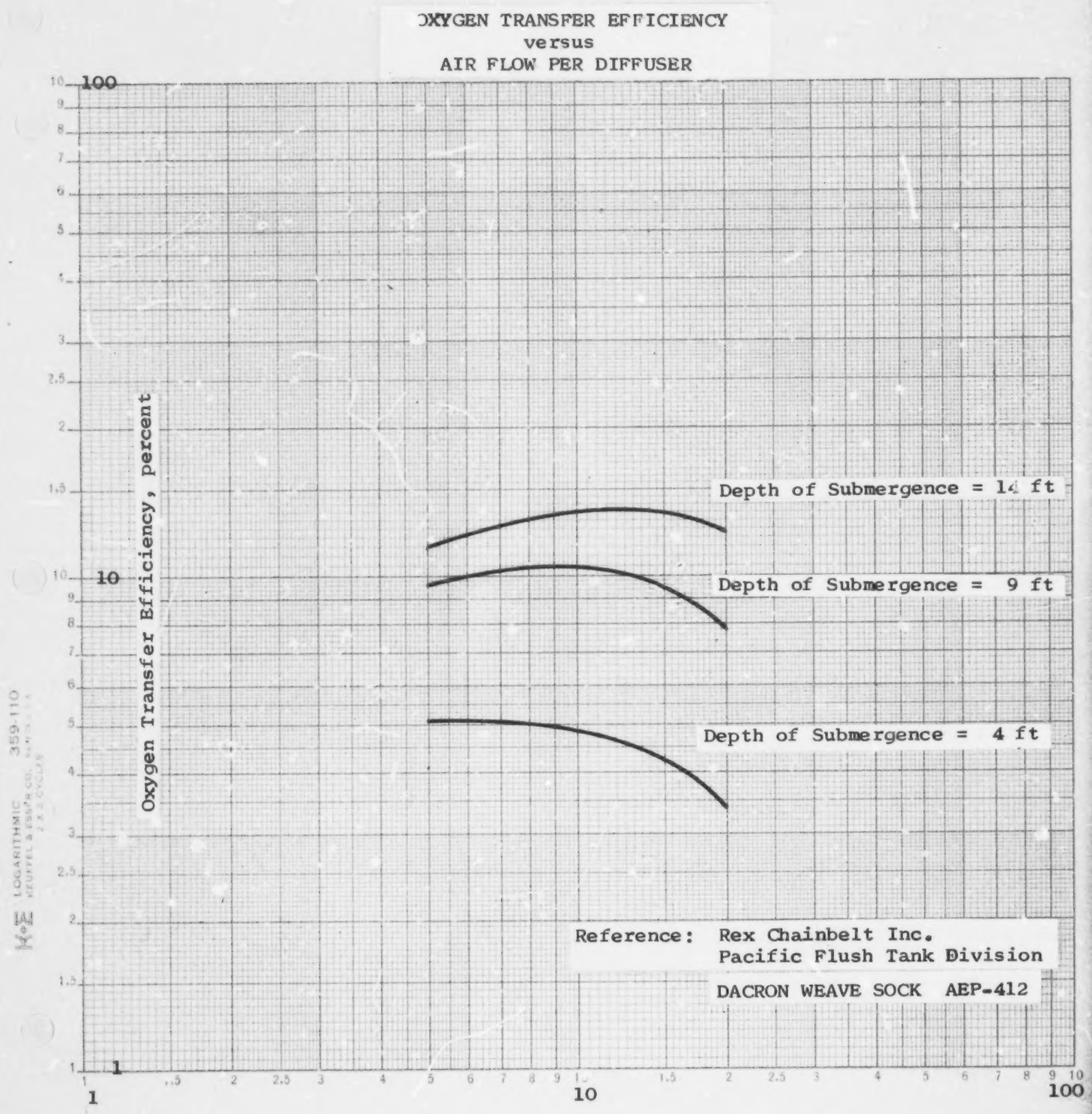

OXYGEN TRANSFER EFFICIENCY
versus
AIR FLOW PER DIFFUSER
Oxygen Transfer Efficiency, percent
Depth of Submergence = 14 ft
Depth of Submergence = 9 ft
Depth of Submergence = 4 ft
Reference: Rex Chainbelt Inc.
Pacific Flush Tank Division
DACRON WEAVE SOCK AEP-412
Air Flow per Diffuser, scfm

Figure 2

given by Kormanik (equation 14) was used to correct for depth of submergence and air flow per diffuser. The standard aeration efficiency at 13 ft. submergence and 8 scfm per diffuser was taken as 8%. The value used for ALPHA was 0.9.

Since the effect of design variables on the efficiency of mechanical aerators is not well established, the following simplier relationship will be used to correct the oxygen transfer variable for mechanical aerators:

$$HPHRO = HPHROO*(CSW-DOUT)/9.02*ALPHA*1.025**(TL-20.) \quad (15)$$

The performance measures for mechanical and diffused air given in equations (14) and (15) can now be used with equations (5) and (10) to compute the design for completely mixed basins. In the sample calculations HPHROO is set equal to 3.5 lb. oxygen dissolved per horsepower-hr.

In designing for completely mixed mechanical aeration systems, it is also necessary to consider the fact that mechanical aerators can be supplied only in a finite number of horsepower sizes. In the sample calculations, the range of sizes available from EIMCO-ENVIROTECH was used. The sizes used were 5, 7½, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 125, and 150 horsepower. The procedure is to first compute the required horsepower then to round up to the next available size. If the horsepower is greater than 150, the required horsepower is divided by 150 and the next larger integer is taken as the number of 150 HP aerators required. The size of the basin is then recomputed, based on the number of 150 HP aerators to be used. If the available list of sizes is known, the list can be easily inserted in the program.

For plug flow diffused air systems installed in outlet channels, the problem is somewhat different. We must consider an element of the outlet stream moving down the channel and express the variation of dissolved oxygen concentration with time. This can be written

as follows:

$$d(DO)/dt = AERK1*(CSW-DO) - AERK2 \quad (16)$$

$$AERK1 = .33347*CFMMG*AERFF \quad (17)$$

The term CFMMG is computed from equation (9) where TD is the channel depth and TW is the channel width. Aeration efficiency is computed from equation (14) except that the term (CSW-DOUT) is omitted. This is necessary because DOUT varies along the channel and it is represented in equation (16) above as DO.

Now, equation (16) above can be integrated along the channel with the following results:

$$(AERK1*(CSW-DOUT)-AERK2)/(AERK1*(CSW-DOIN)-AERK2) = 1./2.71828**AERK1*T \quad (18)$$

In this equation (T) is the detention time along the channel in days. The velocity of flow in the channel is computed as follows:

$$VFM = Q*38.76/TD/TW \quad (19)$$

The length of channel required is, therefore, simply VFM*T*1440.

When a particular channel is being considered, the width and depth of the channel will be known. For the general case, we know that the velocity in the channel should be at least 1 fps to prevent settling out of solids. Since the mass flow in cfs equals the product of channel crossectional area in square feet times the average flow velocity in fps, we can compute the crossectional area of water in the channel as 0.646 times the average flow in mgd.

The program for post aeration has been used to compute the size of aeration equipment and structures for mechanical aeration in concrete basins, for diffused air in the outlet channel, and for diffused air in aeration basins.

When mechanical aeration is specified, the size of the basin required is computed by the program. The length of the basin is set

equal to the width except when the horsepower required is greater than 150 HP. The results of computations where the influent is 1 mg/l of dissolved oxygen and the effluent concentration varies between 2-7 mg/l are shown in Figure 3.

The computations involving installation of diffusers in the outlet channel were made assuming that the flow velocity in the channel at the average flow was 1 foot/second. The crossectional area for 1 mgd, using this assumption, was only .646 sq. ft. Since this is clearly too small for installation of diffusers, only the 10 mgd and 100 mgd plants were considered candidates for aeration in the outlet channel. The channel assumed for the 10 mgd plant was 2.5 ft. deep and 3 ft. wide. The depth of the diffusers was taken as 1.5 ft. For the 100 mgd plant, a channel 10 ft. wide and 8 ft. deep was assumed with the diffusers placed 6 ft. from the water surface. The scf/gal and the length of channel required for the 10 mgd and 100 mgd plants are shown plotted in Figure 4.

For completely mixed aeration basins equipped with diffused air, the tank dimensions assumed at the 1 mgd size were 10 ft. wide and 5 ft. deep with the diffusers 4 ft. from the water surface. For the 10 mgd and 100 mgd sizes, the tank width was taken as 24 ft. and the tank depth as 15 ft. The diffusers were placed 13 ft. below the water surface. The results of these computations are shown in Figure 5.

Two separate digital computer programs have been developed for post aeration. Listings for both programs and a set of definitions of terms used are given in the Appendix. The first program is arranged to size the equipment and structures with varying inputs. The second program, entitled POSTA, is a subroutine to be used with the Executive Program.[8] The Executive Program is used for design and cost estimation of any wastewater treatment system composed of unit processes arranged in a specific configuration. The program POSTA is used as one of the unit processes in the Executive Program.

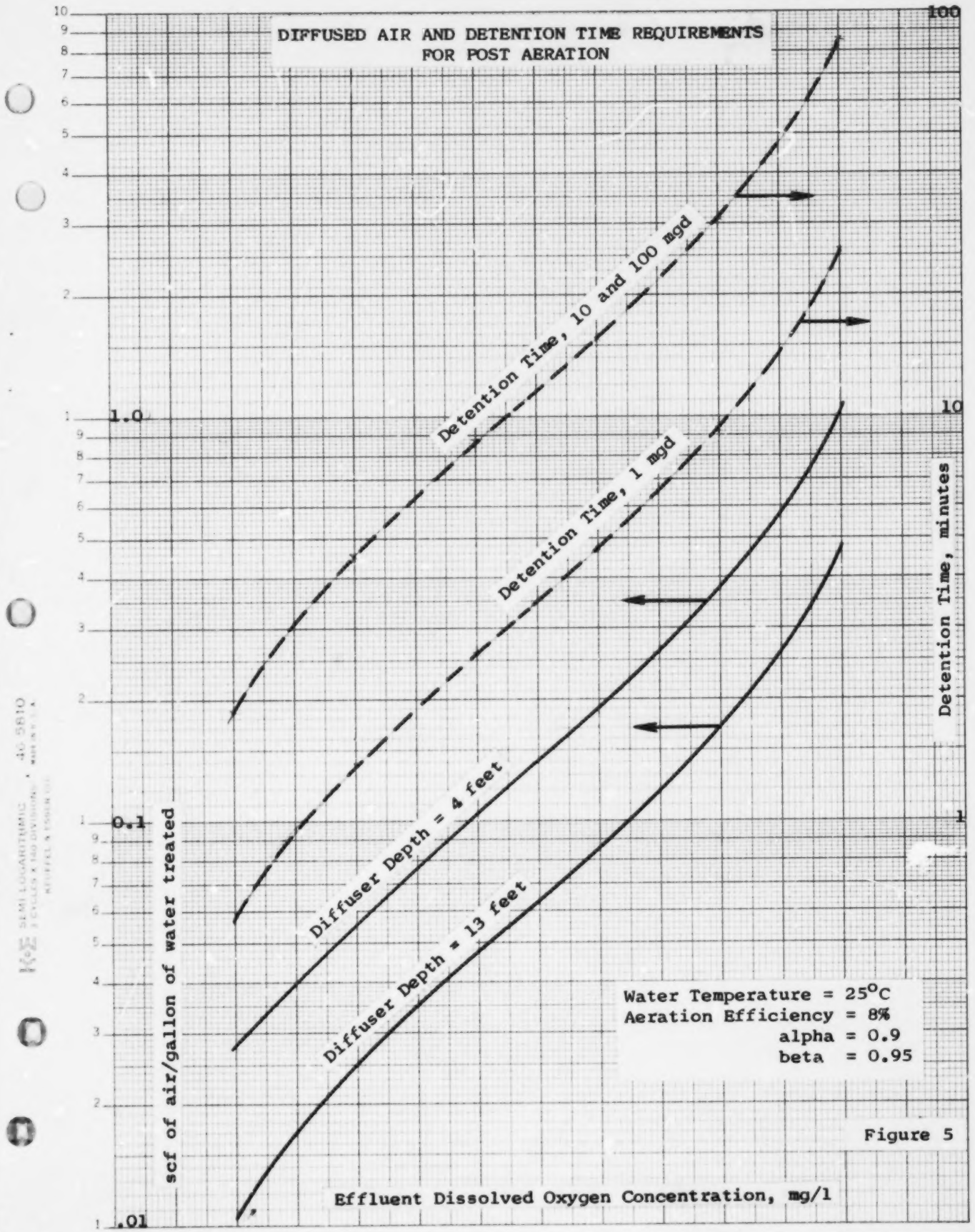

DIFFUSED AIR AND DETENTION TIME REQUIREMENTS FOR POST AERATION
Detention Time, 10 and 100 mgd
Detention Time, 1 mgd
Diffuser Depth = 4 feet
Diffuser Depth = 13 feet
Water Temperature = 25°C
Aeration Efficiency = 8%
alpha = 0.9
beta = 0.95
scf of air/gallon of water treated
Detention Time, minutes
Effluent Dissolved Oxygen Concentration, mg/l
1.0
0.1
.01
100
10
1
1
2
3
4
5
6
7
8

Figure 5

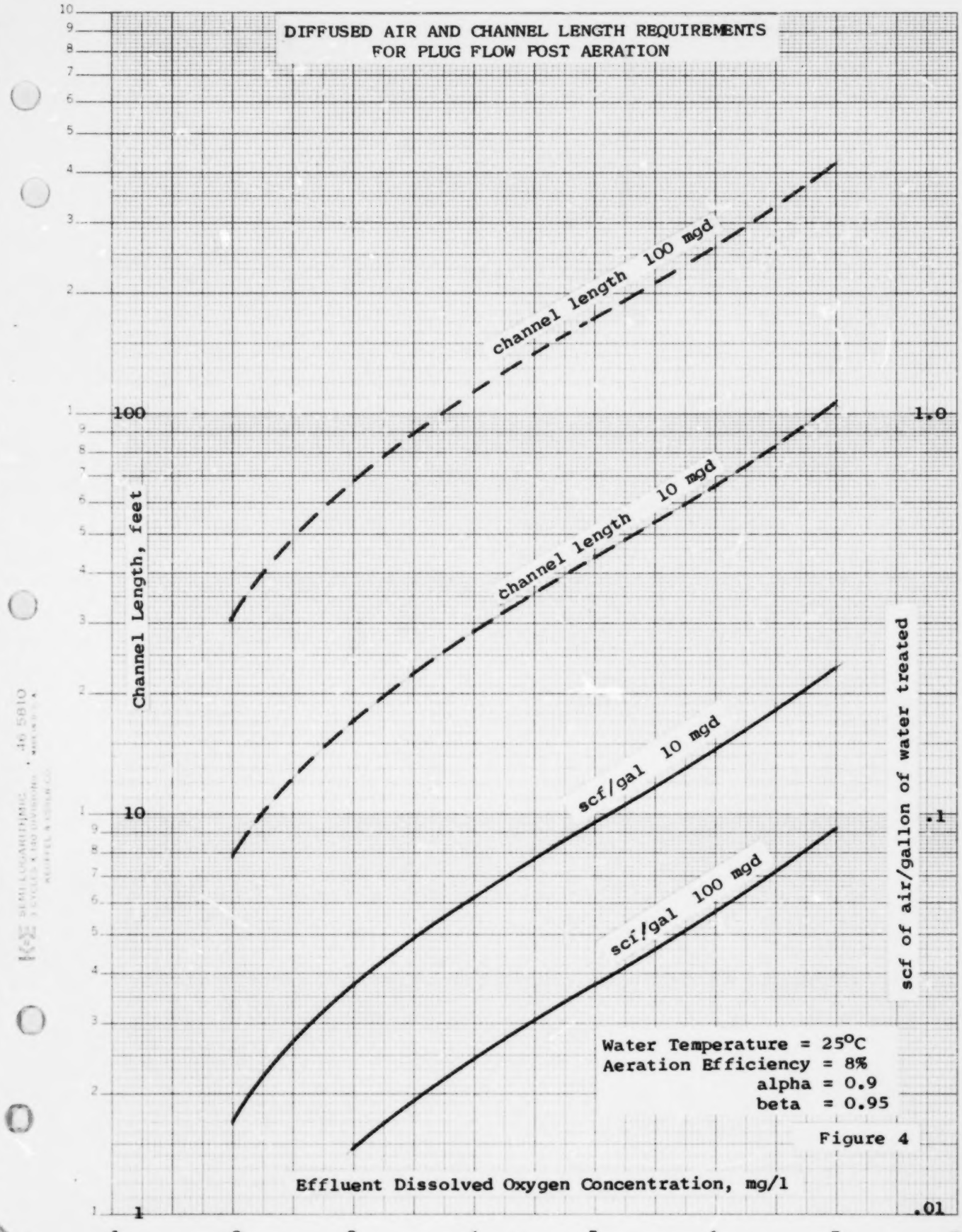

DIFFUSED AIR AND CHANNEL LENGTH REQUIREMENTS
FOR PLUG FLOW POST AERATION
channel length 100 mgd
channel length 10 mgd
scf/gal 10 mgd
sci/gal 100 mgd
Channel Length, feet
scf of air/gallon of water treated
100
10
1
1.0
.1
.01
Water Temperature = 25°C
Aeration Efficiency = 8%
alpha = 0.9
beta = 0.95
Effluent Dissolved Oxygen Concentration, mg/l
1
2
3
4
5
6
7
8

Figure 4

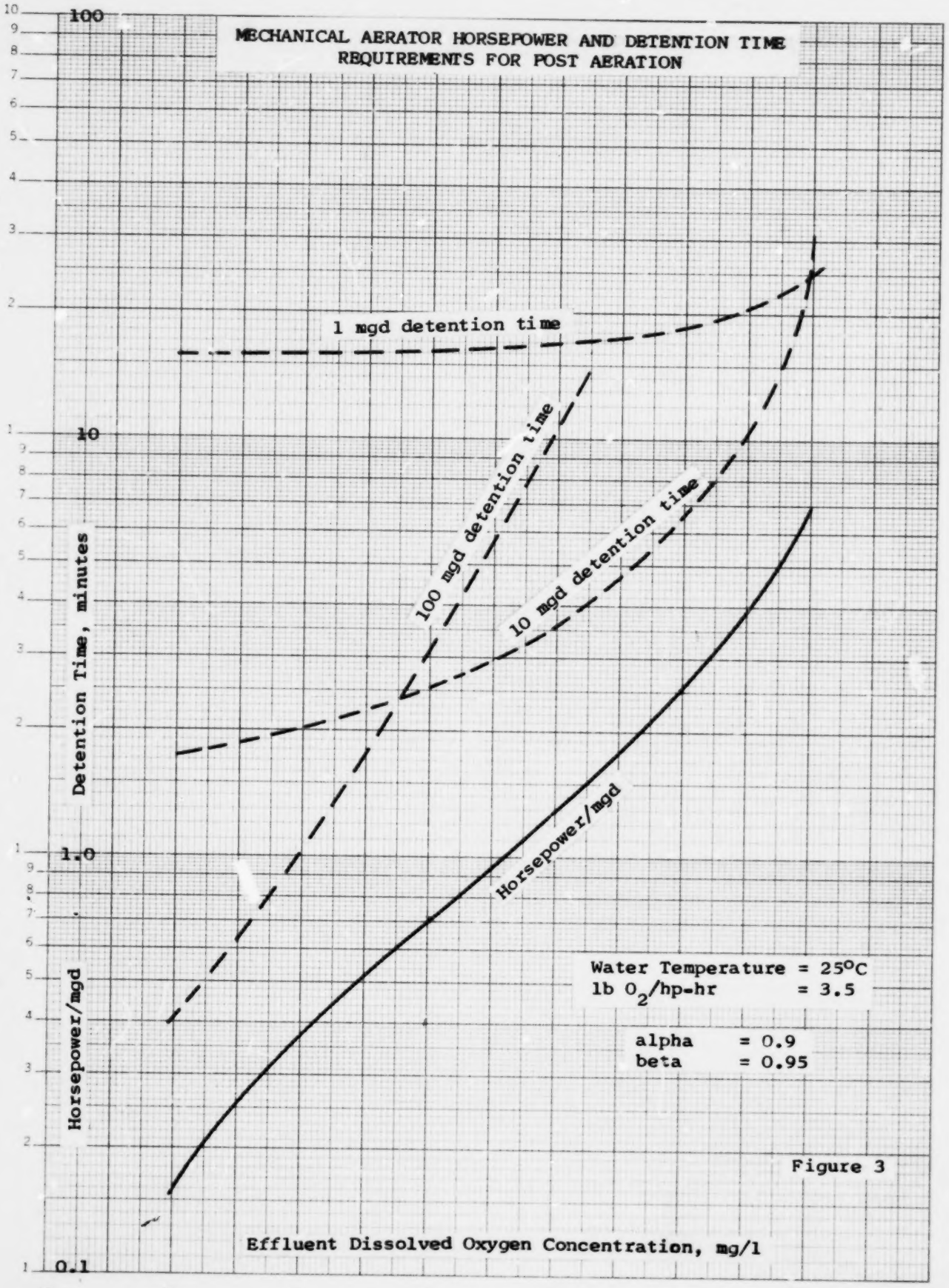

MECHANICAL AERATOR HORSEPOWER AND DETENTION TIME REQUIREMENTS FOR POST AERATION
1 mgd detention time
100 mgd detention time
10 mgd detention time
Horsepower/mgd
Detention Time, minutes
Horsepower/mgd
Water Temperature = 25°C
lb O_2/hp-hr = 3.5
alpha = 0.9
beta = 0.95
Effluent Dissolved Oxygen Concentration, mg/l
100
10
1.0
0.1
1
2
3
4
5
6
7
8

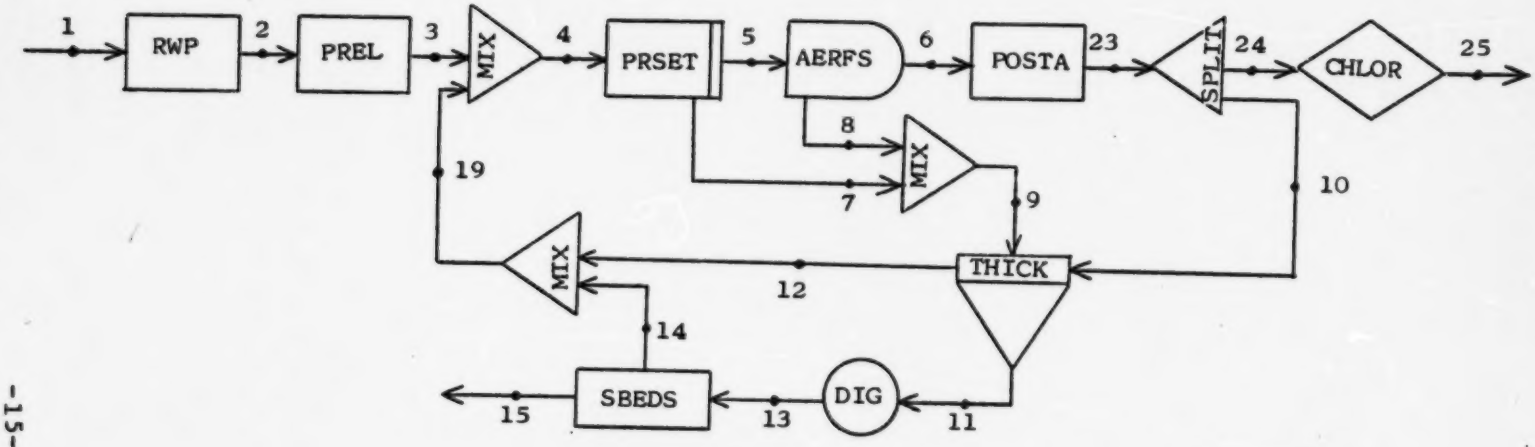
Figure 3

To illustrate the use of POSTA, the Executive Program has been used to compute the cost of post aeration in the two treatment systems shown diagramatically in Figure 6. System 1 consists of raw wastewater pumping (RWP), preliminary treatment (PREL), primary sedimentation (PRSET), aerator-final settler (AERFS), post aeration (POSTA), chlorination (CHLOR), gravity sludge thickening (THICK), anaerobic digestion (DIG), and sludge drying beds (SBEDS). MIX and SPLIT symbols on the diagram represent stream mixing and splitting. The dissolved oxygen concentration into post aeration was taken as 1 mg/l and the dissolved oxygen out of the process as 6 mg/l. All other assumptions made for post aeration are given in the earlier sections of this report. The water temperature was set at 25°C.

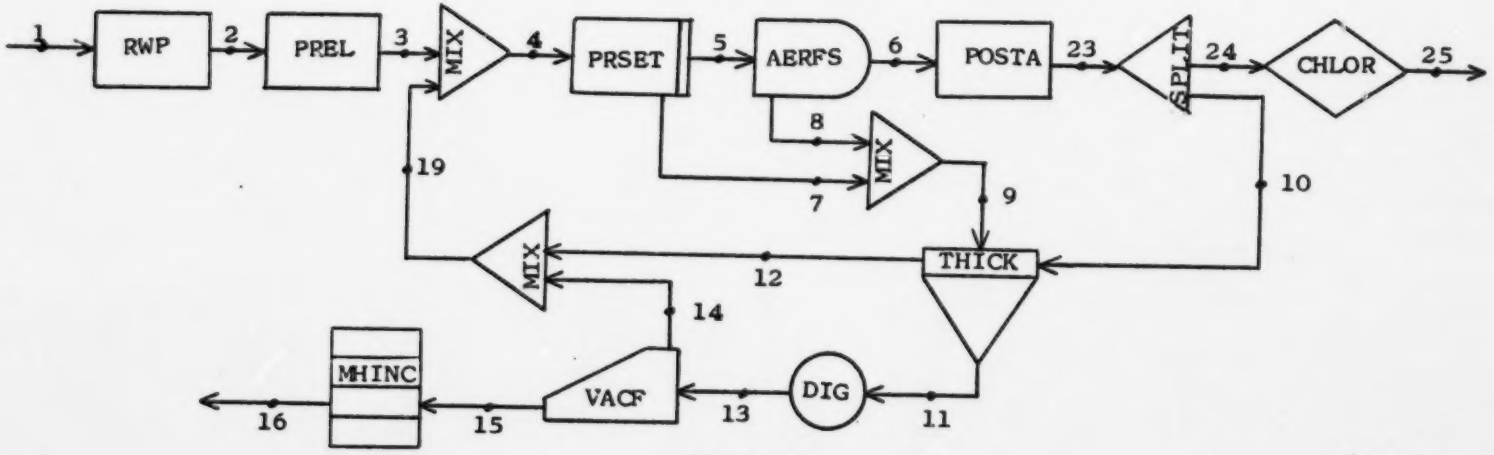
System 2 is similar to System 1 except that vacuum filtration (VACF) and multiple hearth incineration (MHINC) are used in place of sludge drying beds. Based on previous results, it was concluded that it is generally preferable to use sludge drying beds for the smaller activated sludge plants. At plant sizes greater than 10 mgd, vacuum filtration and multiple hearth incineration for sludge disposal are often preferred. System 1 was evaluated at 1, 3, and 10 mgd, and System 2 was evaluated at 30 and 100 mgd.

The cost of complete plants, including post aeration, is shown in Table I. Total treatment cost is the sum of operating and maintenance cost plus amortization cost at 6% and 25 years. The cost of post aeration alone is shown in Table II. These costs include a proportional amount of the ancillary costs such as engineering, interest during construction, etc. All capital and operating and maintenance costs for post aeration were taken from reference 3.

WASTEWATER TREATMENT PLANT SYSTEMS USING POST AERATION



SYSTEM 1



SYSTEM 2

Figure 6

COST OF ACTIVATED SLUDGE PLANTS
with
POST AERATION

mgd	Mechanical Aerators	Diffused Air Plug Flow	Diffused Air Complete Mix
1 (SBEDS)	893,927	875,920	904,643
	18.619	18.955	19.318
	37.777	37.728	38.706
3 (SBEDS)	1,507,098	1,506,782	1,560,225
	9.596	9.779	10.096
	20.362	20.544	21.242
10 (SBEDS)	3,106,217	3,123,688	3,211,676
	5.788	5.924	5.966
	12.445	12.619	12.850
30 (MHINC)	10,738,896	10,724,794	10,917,210
	4.645	4.710	4.747
	12.317	12.372	12.546
100 (MHINC)	29,587,104	29,241,328	29,941,592
	3.456	3.425	3.545
	9.797	9.692	9.962

Capital Cost is in dollars (January 1971)
Operation and Maintenance Cost is in cents/1000 gallons
Total Treatment Cost is in cents/1000 gallons
DOUT is the demand dissolved oxygen out of the post aeration process: 6 mg/l

Table I

COST OF POST AERATION ONLY

mgd	Mechanical Aerators	Diffused Air Plug Flow	Diffused Air Complete Mix
1 (SBEDS)	43,760	25,129	54,836
	1.324	1.660	2.023
	2.261	2.199	3.198
3 (SBEDS)	45,653	45,330	99,980
	.516	.700	1.016
	.842	1.024	1.730
10 (SBEDS)	75,427	93,140	182,302
	.216	.352	.394
	.377	.552	.785
30 (MHINC)	207,895	193,735	386,945
	.184	.248	.285
	.332	.387	.561
100 (MHINC)	582,699	236,014	938,106
	.115	.084	.204
	.240	.135	.405

Capital Cost is in dollars (January 1971)
Operation and Maintenance Cost is in cents/1000 gallons
Total Treatment Cost is in cents/1000 gallons
DOUT is the demand dissolved oxygen out of the post aeration process: 6 mg/l

Table II

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APPENDIX

The use of the FORTRAN mode of expression has several advantages. First, all expressions can be written using ordinary typewriter symbols on a single line. Second, ambiguity and misunderstanding can be avoided when the simple rules are understood. Third, when a computer program is being described, the variable names used in the digital computer program can be used thus making the computations performed better understood by the reader.

FORTRAN provides five basic operations: addition, subtraction, multiplication, division, and exponentiation. Each of the operations is represented by a distinct symbol as follows:

Addition	+
Subtraction	-
Multiplication	*
Division	/
Exponentiation	**

In writing FORTRAN expressions, using the operations shown above, the following rules must be observed:

1. Two symbols of operation must not appear next to each other. Thus, A*-B is not a valid expression but A*(-B) is valid.

2. Parentheses must be used to indicate groupings just as in ordinary mathematical notation. Thus, $(X+Y)^3$ must be written (X+Y)**3 to convey the correct meaning. Again, A-B+C and A-(B+C) are both legitimate expressions, but they do not mean the same thing.

3. When the hierarchy of operations in an expression is not completely specified by the use of parentheses, the sequence of operations is as follows: All exponentiations are performed first, then all multiplications and divisions, and finally all additions and subtractions.

4. When the order of consecutive multiplication and/or division or addition and/or subtraction is not specified by the use of parentheses, the operations are performed from left to right. Thus, A/B/C would be taken to mean A/(B*C) not (A*C)/B. Also, A-B+C would mean (A-B)+C not A-(B+C).

FORTRAN provides for the use of certain common mathematical functions, such as square root, logarithm, exponential, sine, cosine or absolute value of the variable X, and COSF(X) means the cosine of the angle X expressed as radians.

DEFINITIONS OF FORTRAN VARIABLES
FOR POST AERATION

FORTRAN Variable	Definition	Nominal Value
DOIN	Dissolved Oxygen Concentration into post aeration, mg/l	1.0
DOUT	Dissolved Oxygen Concentration in effluent stream from post aeration	2-7 mg/l
TL	water temperature, degrees Centigrade	20
TD	tank depth, ft.	5-15
TW	tank width, ft.	10-24
CABR	rate constant for synthesis, 1/(days x mg/l)	.024
CE	endogenous respiration rate constant, dimensionless	.125
CY	yield coefficient	.65
ALPHA	rate constant for oxygenation in secondary effluent/rate constant for oxygenation in pure water	.96
BETA	saturation value in secondary effluent/saturation value in pure water	.95
CFMDF	standard cubic feet of air per minute per diffuser	15
DIFFT	diffusers per foot of tank length	1
AERFO	aeration efficiency at standard conditions	.08
DMATX(15,N)	excess capacity factor applied to aeration tank volume	1.25
DMATX(16,N)	excess capacity factor applied to aeration equipment, mechanical or diffused air	1.25
HPHRO	efficiency measure for mechanical aerators, lb. oxygen transferred per hp-hr	3.5

Definitions (Cont'd.)

FORTRAN Variable	Definition	Nominal Value
DD	depth of diffuser below the water surface, feet	4-13
DMATX(19,N)	altitude of plant site above sea level, feet	200
S	concentration of BOD in aeration basin, mg/l	20
XA	concentration of active solids in aeration basin, mg/l	8
SMATX(2,IS1)	volume flow of influent stream, mgd	
CSS	saturation value for oxygen in pure water, mg/l	9.02
RP	atmospheric air pressure at plant site/sea level atmospheric pressure	
CSW	saturation value for oxygen in secondary effluent, mg/l	8.1
HP	installed brake horsepower for mechanical aerators	
VCF	volume of aerator, cu. ft.	
VMG	volume of aerator, mg	
WIDTH	mechanical aerator basin width, ft.	
DEPTH	mechanical aerator basin depth, ft.	
HPMG	mechanical aerator horsepower per mg of basin volume	
DAYS	aeration basin detention time, days	
TMIN	aeration basin detention time, minutes	
CFMMG	standard cubic feet of air per mg of basin volume	
ABRFF	aeration efficiency corrected to plant conditions	
CLEN	aeration channel length, ft.	
TLEN	aeration basin length, ft.	

EXECUTIVE PROGRAM
POST AERATION SUBROUTINE (POSTA)
DECISION AND OUTPUT MATRIX VARIABLES

DMATX

DMATX(1,N) = ITYPE, program control: -1 = mechanical aeration system is used,
0 = diffused air aeration system is used (plug flow),
+1 = diffused air aeration system is used (complete mix)

DMATX(2,N) = L, program control: set equal to the process number (N) given to the aeration (ABRFS) process to allow the POSTA subroutine to use output parameters calculated in the aeration process

DMATX(3,N) = DOIN, dissolved oxygen concentration entering the post aeration process, mg/l

DMATX(4,N) = DOUT, dissolved oxygen concentration in the effluent stream from the post aeration process, mg/l

DMATX(5,N) = TL, water temperature, degrees centigrade

DMATX(6,N) = TD, tank depth (for diffused air only), feet

DMATX(7,N) = TW, tank width (for diffused air only), feet

DMATX(8,N) = ABRFO, aeration efficiency at standard conditions (for diffused air only), fraction

DMATX(9,N) = HPHRO, efficiency measure for mechanical aerators, lbs. of oxygen transferred per hp-hour

DMATX(10,N) = ALT, altitude of plant site above sea level, feet

DMATX(11,N) = CFMDF, standard cubic feet of air per minute per diffuser

DMATX(12,N) = DIFFT, diffuser per foot of tank length

DMATX(13,N) = DD, depth of diffuser below the water surface, feet

DMATX(15,N) = ECF, excess capacity factor (post aeration basin)

DMATX(16,N) = ECF, excess capacity factor (air supply system)

OMATX

OMATX(1,N) = VABR, volume of the post aeration basin, cu ft/1000

OMATX(2,N) = CFM, air requirement for the diffusers, cfm

OMATX(3,N) = HP, installed brake horsepower for mechanical aerator, hp

OMATX(4,N) = TMIN, post aeration basin detention time, minutes

OMATX(5,N) = VMG, volume of the post aeration basin, mg

OMATX(6,N) = ABRFF, aeration efficiency corrected to plant conditions

OMATX(7,N) = CLEN, aeration channel length (plug flow), feet

OMATX(8,N) = HP1, installed brake horsepower (HP) rounded off to the next higher available size mechanical aerator, hp

OMATX(9,N) = XN, number of mechanical aerators required

OMATX(10,N) = THP, total mechanical aeration horsepower required (HP1*XN), hp

OMATX(11,N) = WIDTH, mechanical aeration basin width, feet

OMATX(12,N) = DEPTH, mechanical aeration basin depth, feet

OMATX(13,N) = TLEN, aeration basin length (diffused air complete mix), feet

```
      SUBROUTINE POSTA
      INTEGER OS1,OS2
      DIMENSION SIZE(14)
      COMMON SMATX(20,25),TMATX(20,25),DMATX(20,20),OMATX(20,20),IP(25),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),
     . ACOST(20,5),TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND
      DATA SIZE/5.,7.5,10.,15.,20.,25.,30.,40.,50.,60.,75.,100.,
     . 125.,150./
      ITYPE=DMATX(1,N)
      L=DMATX(2,N)
      DOIN=DMATX(3,N)
      DOUT=DMATX(4,N)
      TL=DMATX(5,N)
      TD=DMATX(6,N)
      TW=DMATX(7,N)
      AERFO=DMATX(8,N)
      HPHRO=DMATX(9,N)
      ALT=DMATX(10,N)
      CFMDF=DMATX(11,N)
      DIFFT=DMATX(12,N)
      DD=DMATX(13,N)
      IF(7.5-DOUT) 2,4,4
    2 WRITE(IO,3)
    3 FORMAT(////,10X,'DEMAND DOUT OF POST AERATION IS TOO HIGH',////)
    4 CAER=.024
      CY=.65
      CE=.125
      ALPHA=.9
      BETA=.95
      S=SMATX(8,IS1)+SMATX(17,IS1)
      XA=OMATX(9,L)*OMATX(3,L)
      CFM=0.
      HP=0.
      CFMMG=0.
      HPMG=0.
      DEPTH=0.
      TMIN=0.
      VAER=0.
      VMG=0.
      VCF=0.
      VDEL=0.
      WIDTH=0.
      AERFF=0.
      CLEN=0.
      VFM=0.
      TLEN=0.
      HP1=0.
      XN=0.
      THP=0.
      DO 5 I=2,17
    5 SMATX(I,OS1)=SMATX(I,IS1)
      CSS=14.652-.410220*TL+.007991*TL**2.-.000078*TL**3.
      RP=(760.-.025*ALT)/760.
      CSW=RP*CSS*BETA
      IF(ITYPE) 10,40,50
   10 VMG=0.
      AERK1=.31942*(CSW-DOUT)*HPHRO*ALPHA*1.025**(TL-20.)
      AERK2=.58*CAER*XA*S/CY+1.16*CE*XA
      NT=0
```

```
   20 NT=NT+1
      HP=(SMATX(2,IS1)*(DOUT-DOIN)+AERK2*VMG)/AERK1*DMATX(15,N)
      VCF=(17.+.53*HP)**2.*(5.+.07*HP)
      VMGP=VMG
      VMG=VCF*7.48/1000000.*DMATX(16,N)
      VDEL=ABS(VMG-VMGP)
      IF(NT-25) 26,26,24
   24 WRITE(IO,25)
   25 FORMAT(////,10X,'POST AERATION ITERATION DOES NOT CONVERGE',////)
      GO TO 30
   26 IF(VDEL-.0001) 30,30,20
   30 DO 34 I=1,14
      IF(HP-SIZE(I)) 32,32,34
   32 HP1=SIZE(I)
      XN=1.
      GO TO 36
   34 CONTINUE
      HP1=150.
      XN=HP/150.
      IXN=XN
      XN=IXN+1
   36 THP=HP1*XN
      WIDTH=17.+.53*HP1
      DEPTH=5.+.07*HP1
      VCF=DEPTH*WIDTH**2.
      VMG=(VCF*7.48/1000000.)*XN
      HPMG=THP/VMG
      DAYS=VMG/SMATX(2,IS1)
      TMIN=DAYS*1440.
      VAER=VMG*1000./7.48
      GO TO 60
   40 CFMMG=CFMDF*DIFFT*1000000./TD/TW/7.48
      AERFF=AERFO*(DD/13.)**.66666*(8./CFMDF)**.2
      AERK1=.33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)
      AERK2=.58*CAER*XA*S/CY-1.16*CE*XA
      TEMP=(AERK1*(CSW-DOUT)-AERK2)/(AERK1*(CSW-DOIN)-AERK2)
      DAYS=-1.*ALOG(TEMP)/AERK1
      TMIN=DAYS*1440.
      VFM=SMATX(2,IS1)*38.76/TD/TW
      CLEN=VFM*TMIN
      CFM=CLEN*CFMDF*DIFFT*DMATX(15,N)
      GO TO 60
   50 CFMMG=CFMDF*DIFFT*1000000./TD/TW/7.48
      AERFF=AERFO*(DD/13.)**.66666*(8./CFMDF)**.2
      AERK1=.33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)
      AERK2=.56*CAER*XA*S/CY-1.16*CE*XA
      VMG=SMATX(2,IS1)*(DOUT-DOIN)/(AERK1*(CSW-DOUT)-AERK2)*DMATX(16,N)
      DAYS=VMG/SMATX(2,IS1)
      TMIN=DAYS*1440.
      TLEN=VMG*1000000./TD/TW/7.48
      VAER=VMG*1000./7.48
      CFM=CFMMG*VMG*DMATX(15,N)
   60 IF(ITYPE) 62,68,62
   62 X=ALOG(VAER)
      CCOST(N,1)=EXP(2.180040+.351346*X+.064188*X**2.-.003403*X**3.)*
     . 1000.
      CHRS=0.
      XMHRS=0.
      TMSU=0.
```

```
      COSTO(N,1)=0.
   68 IF(ITYPE) 70,80,80
   70 X=ALOG(THP)
      IF(THP-20.) 72,74,74
   72 CCOST(N,2)=20000.
      GO TO 76
   74 CCOST(N,2)=EXP(2.848804-.223685*X+.142476*X**2.-.005985*X**3.)*
     . 1000.
   76 X=ALOG(THP/DMATX(15,N))
      IF(THP/DMATX(15,N)-40.) 77,78,78
   77 OHRS=600.
      XMHRS=300.
      GO TO 79
   78 OHRS=EXP(6.716272-.310684*X+.112744*X**2.-.004877*X**3.)
      XMHRS=EXP(4.251092+.467681*X+.008276*X**2.)
   79 XKW=.8*THP/DMATX(15,N)
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      PCFM=THP/DMATX(15,N)/8.1/144.*(33000.*.8)/1000.
      SCOST=EXP(.621382+.482047*ALOG(PCFM))*1000.
      TMSU=ECOST+SCOST
      COSTO(N,2)=((OHRS+XMHRS)*OHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      GO TO 90
   80 X=ALOG(CFM/1000.)
      IF(CFM/1000.-.1) 82,84,84
   82 CCOST(N,2)=13000.
      GO TO 86
   84 CCOST(N,2)=EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*
     . 1000.
   86 X=ALOG(CFM/1000./DMATX(15,N))
      IF(CFM/1000./DMATX(15,N)-1.) 87,88,88
   87 OHRS=850.
      XMHRS=350.
      GO TO 89
   88 OHRS=EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+
     . .003300*X**4.)
   89 CHP=CFM/DMATX(15,N)*8.1*144./(33000.*.8)
      XKW=.8*CHP
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      SCOST=EXP(.621382+.482047*X)*1000.
      TMSU=ECOST+SCOST
      COSTO(N,2)=((OHRS+XMHRS)*OHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
   90 OMATX(1,N)=VAER
      OMATX(2,N)=CFM
      OMATX(3,N)=HP
      OMATX(4,N)=TMIN
      OMATX(5,N)=VMG
      OMATX(6,N)=AERFF
      OMATX(7,N)=CLEN
      OMATX(8,N)=HP1
      OMATX(9,N)=XN
      OMATX(10,N)=THP
      OMATX(11,N)=WIDTH
      OMATX(12,N)=DEPTH
      OMATX(13,N)=TLEN
      RETURN
      END
```

EXECUTIVE
DIGITAL COMPUTER PROGRAM
FOR
PRELIMINARY DESIGN OF WASTEWATER TREATMENT SYSTEMS

BY
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CINCINNATI, OHIO

10 MGD TEST OF POST AERATION FEBRUARY 1973 SBEDS

SYSTEM DIAGRAM
INPUT DATA

K	N	PROCESS		IS1	IS2	OS1	OS2	III
0	1	15	RWP	1	0	2	0	2
0	2	1	PREL	2	0	3	0	2
1	0	4	MIX	3	19	4	0	1
0	3	2	PRSET	4	0	5	7	0
0	4	3	AERFS	5	0	6	8	0
0	5	19	POSTA	6	0	23	0	0
0	0	5	SPLIT	23	0	24	10	0
0	0	4	MIX	7	8	9	0	0
0	6	8	THICK	9	10	11	12	0
0	7	6	DIG	11	0	13	0	0
0	8	10	SBEDS	13	0	15	14	0
1	0	4	MIX	12	14	19	0	1
0	9	12	CHLOR	24	0	25	0	2
9	0	0		0	0	0	0	0

STREAM CHARACTERISTICS

VOLUME FLOW, MILLIONS OF GALLONS PER DAY
CONCENTRATIONS, MILLIGRAMS PER LITER

S 1.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	10.000	105.000	30.000	10.000	2.000	30.000	140.200	223.600
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	250.000	43.000	11.000	19.100	4.000	500.000	59.840	253.600
S 2.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	10.000	105.000	30.000	10.000	2.000	30.000	140.200	223.600
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	250.000	43.000	11.000	19.100	4.000	500.000	59.840	253.600
S 3.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	10.000	105.000	30.000	10.000	2.000	30.000	140.200	223.600
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	250.000	43.000	11.000	19.100	4.000	500.000	59.840	253.600
S 4.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	11.833	92.969	26.788	8.957	1.753	26.659	123.823	198.473
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	39.013	11.000	23.496	4.989	500.000	52.385	225.133
S 5.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	11.819	46.543	13.410	4.484	0.877	13.346	61.989	99.361
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	39.013	11.000	23.496	4.989	500.000	52.385	112.707
S 6.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	11.703	5.844	2.231	0.867	0.058	1.853	7.084	13.908
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	15.762
S 7.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.014	37187.898	10715.201	3582.821	701.358	10663.814	49529.390	79389.500
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	39.013	11.000	23.496	4.989	500.000	52.385	90053.312
S 8.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.115	3715.369	1418.654	551.335	37.153	1178.316	4503.731	8842.578
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	10020.892
S 9.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.130	7516.676	2474.416	895.606	112.584	2255.537	9617.070	16854.238
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	16.987	10.999	21.935	5.395	499.999	11.195	19109.773

S10.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	1.703	5.844	2.231	0.867	0.058	1.853	7.084	13.908
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	15.762
S11.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.047	19655.054	6480.667	2347.670	293.406	5901.291	25133.984	44098.718
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.365	10.999	21.749	5.443	499.999	6.293	50000.007
S12.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	1.786	27.688	9.129	3.307	0.413	8.313	35.406	62.121
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.365	10.999	21.749	5.443	499.999	6.293	70.434
S13.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.047	6825.775	6480.667	829.743	103.699	5901.291	645.352	16245.341
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	3789.187	126.036	10.999	1008.402	195.150	499.999	215.117	22146.632
S14.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.047	15.410	14.631	1.873	0.234	13.323	1.456	36.676
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	3789.187	126.036	10.999	1008.402	195.150	499.999	215.117	50.000
S15.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S19.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	1.833	27.367	9.272	3.269	0.408	8.443	34.521	61.458
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	358.656	17.276	10.999	47.469	10.388	499.999	11.737	69.902
S23.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	11.703	5.844	2.231	0.867	0.058	1.853	7.084	13.908
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	15.762
S24.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	9.999	5.844	2.231	0.867	0.058	1.853	7.084	13.908
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	15.762
S25.	Q	SOC	SNBC	SON	SOP	SFM	SBOD	VSS
	9.999	5.844	2.231	0.867	0.058	1.853	7.084	13.908
	ALK	DOC	DNBC	DN	DP	DFM	DBOD	TSS
	266.837	14.165	11.000	21.735	5.446	500.000	5.918	15.762

PROCESS CHARACTERISTICS

CCOST = CAPITAL COST, DOLLARS
COSTO = OPERATING + MAINTENANCE COST, CENTS/1000 GAL.
ACOST = AMORTIZATION COST, CENTS/1000 GAL.
TCOST = TOTAL TREATMENT COST, CENTS/1000 GAL.

P 1 RAW WASTEWATER PUMPING

HEAD
30.00

	CCOST	COSTO	ACOST	TCOST	ECF
	348493.	0.310	0.746	1.057	1.00

P 2 PRELIMINARY TREATMENT

IPREL
1.0

	CCOST	COSTO	ACOST	TCOST	ECF
	145631.	0.412	0.312	0.724	1.00

P 3 PRIMARY SETTLER B

FRPS	URPS	HPWK	GPS	APS	PGPM
0.50	400.0	14.0	1375.2	10.067	123.

	CCOST	COSTO	ACOST	TCOST	ECF
SETTLER	201389.	0.195	0.431	0.627	1.17
SLUDGE PUMPS	63204.	0.218	0.135	0.353	1.00

P 4 AERATOR-FINAL SETTLER

BCD	MLSS	DEGC	CAER20	DO	AEFF20	URSS	GSS	HEAD	
13.0	2000.	20.00	1.00	1.00	0.05	5.00	700.00	30.00	
BOD2	DOSAT	XRSS	AFS	CAER	CEDR	VAER	VNIT	MLASS	MLBSS
114.3	10.7	0.0078	24.41	1.00	0.124	2.188	2.640	660.	560.
MLNBSS	MLOSS	MLISS	FOOD	RTURN	CNIT	ARCFO	BSIZE	CFPGL	QR
504.	43.	235.	78.0	0.235	0.321	7553135.	5245.	0.63	2.787

	CCOST	COSTO	ACOST	TCOST	ECF
AERATOR	384417.	0.000	0.823	0.823	1.14
BLOWER	261785.	0.025	0.561	1.586	1.00
SLUDGE PUMPS	70501.	0.167	0.151	0.318	1.00
FINAL SETTLER	390371.	0.347	0.836	1.184	1.17

P 5 POST AERATION

ITYPE	L	DOIN	DOUT	TL	TD	TW	AERFO	HPHRO	ALT
-1.	4.	1.0	6.0	25.0	15.0	24.0	0.080	3.50	0.00
CFMCF	DIFFT	DD	VAER	CFM	HP	TMIN	VMG	AERFF	CLEN
15.0	1.0	4.0	7.685	0.	29.20	7.07	0.0574	0.000	0.00
HP1	XN	THP	WIDTH	DEPTH	TLEN				
30.00	1.0	30.00	32.9	7.1	0.00				

	CCOST	COSTO	ACOST	TCOST	ECF
BASIN	30886.	0.000	0.066	0.066	1.00
AIR SUPPLY	44541.	0.216	0.095	0.311	1.00

P 6 GRAVITY THICKENER

TRR	TSS	GTH	GSTH	ATHM	WRT
0.95	50000.	700.0	8.0	3929.6	13.07

							CCOST	COSTO	ACOST	TCOST	ECF
							110125.	0.099	0.236	0.335	1.50
P 7	ANAERCBIC DIGESTER	TD	TDIG	C1DIG	C2DIG	VDIG	CH4	CO2			
		15.0	30.0	0.233	1154.	127.	99611.	52313.			
							CCOST	COSTO	ACOST	TCOST	ECF
							369031.	0.262	0.790	1.053	1.33
P 8	SLUDGE DRYING BEDS	SBL	SOUT	TSS	ASB		CCOST	COSTO	ACOST	TCOST	ECF
		0.007786	0.35	50.	238845.		350366.	0.792	0.750	1.543	1.00
P 9	CHLORINATION	DCL2	TCL2				CCOST	COSTO	ACOST	TCOST	ECF
		8.0	30.0			FEED SYSTEM	75503.	0.599	0.161	0.761	1.00
						CONTACT BASIN	66931.	0.000	0.143	0.143	1.00
	ADMINISTRATIVE AND LABORATORY						CCOST	COSTO	ACOST	TCOST	
							148958.	0.410	0.319	0.729	
	GARAGE AND SHOP						CCOST	COSTO	ACOST	TCOST	
							44081.	0.000	0.094	0.094	
	LABORATORY OPERATION	XLAB					CCOST	COSTO	ACOST	TCOST	
		1.0					0.	0.473	0.000	0.473	
	YARDWORK OPERATION						CCOST	COSTO	ACOST	TCOST	
							0.	0.257	0.000	0.257	

TOTAL PLANT COST

TOTAL CAPITAL COST = 3106217. DOLLARS

TOTAL AMORTIZATION COST = 6.657 CENTS/1000 GAL.

TOTAL O + M COST = 5.788 CENTS/1000 GAL.

TOTAL TREATMENT COST = 12.445 CENTS/1000 GAL.

CCI	WPI	RI	YRS	DHR	PCT	DA	CCINT	XLAB	CKWH
1.506	1.122	0.060	25.0	3.50	0.150	1000.	0.06	1.00	0.013

RATIO	TCAP	YARD	TCC	XLAND	ENG	SUBT1	FISC	SUBT2	XINT
1.344	2311026.	323543.	2634565.	19976.	250393.	2904934.	26847.	2931783.	174432.

ACRE	AF
19.97	0.07822

```
C   POST AERATION PROGRAM BY ELLA HALL AND ROBERT SMITH
      DIMENSION DMATX(20,20),SMATX(10,10)
      IS1=2
      N=1
      IN=2
      IC=5
    1 FORMAT(8F10.3)
    2 FORMAT(I3)
    3 FORMAT(1H1)
    4 FORMAT(3F10.1)
   40 FORMAT(//////,25X,'DECISION MATRIX',/)
   41 FORMAT(1X, 6F10.3,/)
   42 FORMAT(//,6X,'S=',F4.1,3X,'XA=',F4.1,3X,'SMATX(2,IS1)=',F6.1,//)
   43 FORMAT(/,25X,'DECISION MATRIX INPUT'//,4X,'DMATX(1,N)=1,MECHANICAL
     1 AIR',3X,'2,DIFFUSED AIR PLUG FLOW',2X,'3,DIFFUSED AIR COMPLETE MI
     2X',/,4X,'DMATX(2,N)=DOIN',5X,'DMATX(7,N)=CAER',9X,'DMATX(12,N)=CFM
     3DF',/4X,'DMATX(3,N)=DOUT',5X,'DMATX(8,N)=CE',11X,'DMATX(13,N)=DIFF
     4T',/,4X,'DMATX(4,N)=TL',7X,'DMATX(9,N)=CY',11X,'DMATX(14,N)=AERFO'
     5,/,4X,'DMATX(5,N)=TD',7X,'DMATX(10,N)=ALPHA',7X,'DMATX(15,N)=ECF')
   44 FORMAT(4X,'DMATX(6,N)=TW',7X,'DMATX(11,N)=BETA'    ,4X,'DMATX(16,N
     1)=ECF',/,4X,'DMATX(17,N)=HPHRD',/,4X,'DMATX(18,N)=DD',/,4X,'DMATX(
     219,N)=ALTITUDE',//)
   45 FORMAT(3X,'HPMGD=',F10.2)
   46 FORMAT(3X,'CFMGL=',F10.2)
   50 FORMAT(25X,'MECHANICAL AIR',/,2X,'AERK1',3X,'AERK2',5X,'DAYS',6X,
     1'DEPTH',5X,'HP',8X,'HPMG',6X,'TMIN',6X,'VCF',7X,'VDEL',6X,'VMG',
     27X,'WIDTH')
   51 FORMAT(1X,F7.3,1X,F7.2,2X,F7.3,4X,F7.3,2X,F7.3,4X,F7.2,3X,F7.3,
     12X,F7.0,4X,F7.5,3X,F7.4,3X,F7.2,///)
   52 FORMAT(25X,'DIFFUSED AIR PLUG FLOW',/,2X,'AERFF',3X,'AERK1',5X,
     1'AERK2',5X,'CFMG',5X,'CLEN',6X,'DAYS',6X,'TMIN',6X,'VFF')
   53 FORMAT(1X,F7.4,1X,F7.2,3X,F7.2,3X,F7.0,3X,F7.2,3X,F7.4,3X,F7.4,3X,
     1F6.3,///)
   54 FORMAT(25X,'DIFFUSED AIR COMPLETE MIX',/,2X,'AERFF',3X,'AERK1',5X,
     1'AERK2',5X,'CFMG',5X,'DAYS',8X,'TMIN',9X,'TLEN',6X,'VMG')
   55 FORMAT(1X,F7.4,1X,F7.2,3X,F7.2,3X,F7.0,3X,F8.4,3X,F8.4,3X,F8.2,3X,
     1F8.4,///)
```

DECISION MATRIX INPUT

DMATX(1,N)=1,MECHANICAL AIR 2,DIFFUSED AIR PLUG FLOW 3,DIFFUSED AIR COMPLETE MIX
DMATX(2,N)=DOIN DMATX(7,N)=CAER DMATX(12,N)=CFMDF
DMATX(3,N)=DOUT DMATX(8,N)=CE DMATX(13,N)=DIFFT
DMATX(4,N)=TL DMATX(9,N)=CY DMATX(14,N)=AERFO
DMATX(5,N)=TD DMATX(10,N)=ALPHA DMATX(15,N)=ECF
DMATX(6,N)=TW DMATX(11,N)=BETA DMATX(16,N)=ECF
DMATX(17,N)=HPHRD
DMATX(18,N)=DD
DMATX(19,N)=ALTITUDE

```
C                                                  DMATX(18,N)=DD
C                                                  DMATX(19,N)=ALTITUDE
      WRITE(IC,3)
      WRITE(IC,43)
      WRITE(IC,44)
      READ(IN,2)  NCASE
      DO 100 ICASE=1,NCASE
      WRITE(IC,40)
      READ(IN,4)  S,XA,SMATX(2,IS1)
      READ(IN,1)  (DMATX(I,N),I=1,19)
      DMATX(4,N)=25.0
      DMATX(10,N)=0.90
      WRITE(IO,41)  (DMATX(I,N),I=1,19)
      WRITE(IO,42)  S,XA,SMATX(2,IS1)
      DOIN=DMATX(2,N)
      DOUT=DMATX(3,N)
      TL=DMATX(4,N)
      TD=DMATX(5,N)
      TW=DMATX(6,N)
      CAER=DMATX(7,N)
      CE=DMATX(8,N)
      CY=DMATX(9,N)
      ALPHA=DMATX(10,N)
      BETA=DMATX(11,N)
      CFMDF=DMATX(12,N)
      DIFFT=DMATX(13,N)
      AERFC=DMATX(14,N)
      ECF=DMATX(15,N)
      HPHRO=DMATX(17,N)
      DD=DMATX(18,N)
      CSS=14.652-.41022*TL+.0079910*TL**2.-.000077774*TL**3.
      RP=(760.-.025*DMATX(19,N))/760.
      CSW=RP*CSS*BETA
      IF (DMATX(1,N)-1.0)   100,9,25

C   MECHANICAL AIR
    9 CONTINUE
      VMG=0.
      AERK1=.31942*(CSW-DOUT)*HPHRO*ALPHA*1.025**(TL-20.)
      AERK2=.58*CAER*XA*S/CY+1.16*CE*XA
   10 HP=(SMATX(2,IS1)*(DOUT-DOIN)+AERK2*VMG)/AERK1
      VCF=(17.+.53*HP)**2.*(5.+.07*HP)
      VMGP=VMG
      VMG=VCF*7.48/1000000.
      VDEL=ABS(VMG-VMGP)
      IF (VDEL-0.0001)  20,20,10
   20 CONTINUE
      HPMGD=HP/SMATX(2,IS1)
      WRITE(IC,45) HPMGD
      WIDTH=17.+.53*HP
      DEPTH=5.+.07*HP
      HPMG=HP/VMG
      DAYS=VMG/SMATX(2,IS1)
      TMIN=DAYS*1440.
      WRITE(IC,50)
      WRITE(IC,51) AERK1,AERK2,DAYS,DEPTH,HP,HPMG,TMIN,VCF,VDEL,VMG,
     1WIDTH
      GO TO 100
   25 CONTINUE
```

```
      IF(DMATX(1,N)-2.)   100,26,27

C   DIFFUSED AIR PLUG FLOW
   26 CONTINUE
      CFMMG=CFMDF *DIFFT*1000000./TD/TW/7.48
      AERFF=AERFC*(DD/13.)**.66666*(8./CFMDF)**.2
      AERK1=.33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)
      AERK2=.58*CAER*XA*S/CY-1.16*CE*XA
      TEMP=(AERK1*(CSW-DOUT)-AERK2)/(AERK1*(CSW-DOIN)-AERK2)
      DAYS=-1.0*ALOG(TEMP)/AERK1
      TMIN=DAYS*1440.
      VFM=SMATX(2,IS1)*38.76/TD/TW
      CLEN=VFM*TMIN
      CFMGD=CLEN*CFMDF*DIFFT/SMATX(2,IS1)
      WRITE(IC,46) CFMGD
      WRITE(IC,52)
      WRITE(IC,53) AERFF,AERK1,AERK2,CFMMG,CLEN,DAYS,TMIN,VFM
      GO TO 100

C  DIFFUSED  AIR COMPLETE MIX
   27 CONTINUE
      CFMMG=CFMDF *DIFFT*1000000./TD/TW/7.48
      AERFF=AERFC*(DD/13.)**.66666*(8./CFMDF)**.2
      AERK1=.33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)
      AERK2=.58*CAER*XA*S/CY-1.16*CE*XA
      VMG=SMATX(2,IS1)*(DOUT-DOIN)/(AERK1*(CSW-DOUT)-AERK2)
      DAYS=VMG/SMATX(2,IS1)
      TMIN=DAYS*1440.
      TLEN=VMG*1000000./TD/TW/7.48
      CFMGD=CFMMG*VMG/SMATX(2,IS1)
      WRITE(IC,46) CFMGD
      WRITE(IC,54)
      WRITE(IC,55) AERFF,AERK1,AERK2,CFMMG,DAYS,TMIN,TLEN,VMG

  100 CONTINUE
      CALL EXIT
      END
```

DECISION MATRIX

1.000	1.000	5.000	25.000	15.000	24.000
0.024	0.125	0.650	0.900	0.950	15.000
1.000	0.080	1.000	1.000	3.500	4.000
0.000					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

HPMGD= 1.27

MECHANICAL AIR

AERK1	AERK2	DAYS	DEPTH	HP	HPMG	TMIN	VCF	VDEL	VMG	WIDTH
3.149	4.58	0.002	5.891	12.735	512.35	3.579	3323.	0.00005	0.0248	23.74

DECISION MATRIX

1.000	1.000	6.000	25.000	15.000	24.000
0.024	0.125	0.650	0.900	0.950	15.000
1.000	0.080	1.000	1.000	3.500	4.000
0.000					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

HPMGD= 2.49

MECHANICAL AIR

AERK1	AERK2	DAYS	DEPTH	HP	HPMG	TMIN	VCF	VDEL	VMG	WIDTH
2.011	4.58	0.004	6.747	24.963	541.21	6.642	6166.	0.00000	0.0461	30.23

DECISION MATRIX

2.000	1.000	5.000	25.000	2.500	3.000
C.024	0.125	0.650	0.900	0.950	15.000
1.CCO	0.080	1.000	1.000	3.500	1.500
C.CCO					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

CFMGD= 65.78

DIFFUSED AIR PLUG FLOW

AERFF	AERK1	AERK2	CFMMG	CLEN	DAYS	TMIN	VFM
0.0167	1518.12	2.26	267379.	43.85	0.0005	0.8486	51.680

DECISION MATRIX

2.000	1.000	6.000	25.000	2.500	3.000
0.024	0.125	0.650	0.900	0.950	15.000
1.000	0.080	1.000	1.000	3.500	1.500
0.000					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

CFMGD= 98.78

DIFFUSED AIR PLUG FLOW

AERFF	AERK1	AERK2	CFMMG	CLEN	DAYS	TMIN	VFM
0.0167	1518.12	2.26	267379.	65.85	0.0008	1.2743	51.680

DECISION MATRIX

3.000	1.000	5.000	25.000	15.000	24.000
0.024	0.125	0.650	0.900	0.950	15.000
1.000	0.080	1.000	1.000	3.500	13.000
0.000					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

CFMGD= 60.72

DIFFUSED AIR COMPLETE MIX

AERFF	AERK1	AERK2	CFMMG	DAYS	TMIN	TLEN	VMG
0.0705	133.44	2.26	5570.	0.0109	15.6968	40.48	0.1090

DECISION MATRIX

3.000	1.000	6.000	25.000	15.000	24.000
0.024	0.125	0.650	0.900	0.950	15.000
1.000	0.080	1.000	1.000	3.500	13.000
0.000					

S=20.0 XA= 8.0 SMATX(2,IS1)= 10.0

CFMGD= 119.27

DIFFUSED AIR COMPLETE MIX

AERFF	AERK1	AERK2	CFMMG	DAYS	TMIN	TLEN	VMG
0.0705	133.44	2.26	5570.	0.0214	30.8339	79.51	0.2141